
CHAPTER 6

IPM FOR COCKROACHES IN SCHOOLS

INTRODUCTION

Cockroaches are the most important pest in schools, homes, restaurants, and other indoor spaces. They consume human foods and contaminate them with saliva and excrement, produce secretions that impart a characteristic fetid odor, and shed skin scales that cause allergic reactions.

IDENTIFICATION AND BIOLOGY

Except for size and markings, all cockroaches are similar in overall appearance: flattened cricket-like insects with long antennae. The most common cockroaches in the United States are the German, brownbanded, oriental, American, and smoky brown cockroaches. See Table 6-1 for a list of their important characteristics. Figure 6-1 is a pictorial key to these and some other common roaches.

The Asian cockroach (*Blattella asahinai*) has recently become established in Florida. Because this species flies readily and has a greater reproductive potential than the German roach, it may become a serious pest in other areas in the future.

In general, roaches like to squeeze into cracks and crevices in warm places, but as you can see from Table 6-1, the specifics of their habitat differs with the species of roach. The American, oriental, and smoky brown roaches can all live outside, but are forced indoors by cool weather or lack of food.

The life cycle of the cockroach begins with the egg case, or ootheca. In some species the female carries the egg case around with her until just before the eggs hatch and in other species she deposits it in a sheltered place (see Table 6-1). Roaches undergo a gradual metamorphosis in their life cycle. An immature roach, or nymph, looks very much like an adult, but is smaller and wingless. As the nymph grows, it sheds its skin (molts) a number of times. The number of days it takes a cockroach to mature is affected by the temperature: the warmer it is (up to a certain point), the faster the roach grows.

Cockroaches prefer carbohydrates to protein and fat. They will discriminate among foods if given a choice, but when hungry they eat almost anything. Some products not normally considered food—starch-based

paints, wallpaper paste, envelope glue, and bar soaps—contain carbohydrates, and hence are food for roaches.

Cockroaches are generally active at night and remain hidden during daylight. Daylight sightings usually indicate a high population which has overrun available harborage, or a recent emigrant roach seeking shelter.



German Roach

DAMAGE

Cockroaches have not yet been proven to be involved in the natural transmission of any particular human pathogen (this means that they are not a necessary part of the life cycle of a disease organism); however, evidence has been collected that clearly indicates that cockroaches can mechanically transmit a long list of disease-causing organisms. Because roaches wander at will through all types of organic wastes, then travel over kitchen counters, cooking utensils, plates, and silverware, their presence indicates potential contamination of foods and utensils. They can also trigger allergic reactions in sensitive individuals.

DETECTION AND MONITORING

Efforts to control roaches should begin with a monitoring program. Roaches are rarely dispersed everywhere throughout the building. Once they have located a suitable harborage, they tend to concentrate there, leaving periodically to forage for food and water, then returning to the same place. Thus, the first step in monitoring is to locate these roach concentrations. Note that the places where you see signs of roaches are often where they forage and not where they harbor. You may also need to inspect adjacent rooms (above, below, beside). Monitoring must continue after treatment has begun to determine whether control efforts have satisfactorily reduced the cockroach population.

Establishing a Communication System

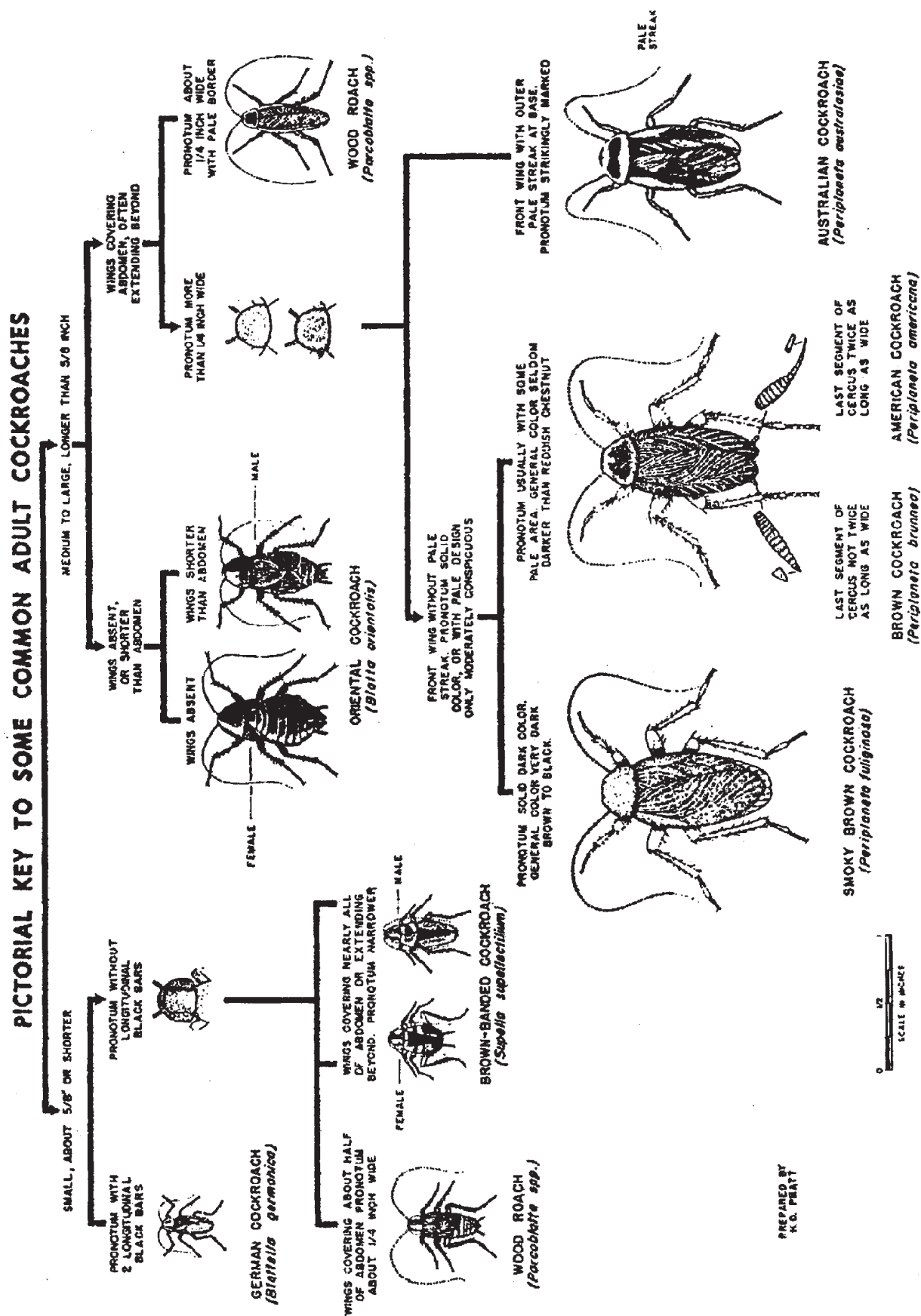
A successful monitoring program depends on clear and frequent communication with principles, teachers, custodians, and food service personnel. These people

Table 6-1. Characteristics of Common Coackroach Species

Please find this table at the end of chapter

¹The number actually hatched can be fewer.
²Other natural enemies include spiders, ants, wasps, beetles, mantids, dragonflies, centipedes, scorpions, toads, geckos, and rats.

Figure 6-1. Pictorial Key To Some Common Adult Cockroaches



have first-hand knowledge of pest sightings, sanitation problems and other contributing factors, as well as the history of control measures in their buildings. With a small investment in time, school personnel can be trained to serve as additional sources of valuable information for the monitoring program.

Make sure personnel understand the following:

- the goals of the cockroach IPM program and the role monitoring plays
- their role in the IPM program (what they can do to help reduce the number of cockroaches and the kind of information they can provide)
- how they can communicate with the pest management technicians (you may want to post log sheets in various locations where people can write down pest sightings and other information)

Visual Inspection

- Construct a map of the premises.
- Mark all the locations where roaches are sighted, or where you see signs of their presence, such as fecal matter, shed skins, egg cases, etc.
- Mark any places that are likely harborage or food sources.
- Note any sanitation problems such as food or grease spills, food or grease buildup behind or under kitchen equipment, or improper garbage disposal procedures.
- Note any leaks or condensation.
- Look for roach entry points such as holes in walls or floors, or around pipes where they enter a wall, around electrical conduits, in vents, etc.
- Use the list of preferred habitats in Table 6-1 to help you decide where to inspect, and see Box 6-A for a list of monitoring tools.

When to Inspect

Schedule at least one inspection after dark. This will give you more information about where the cockroaches are and the level of sanitation at a time when the building is supposed to be clean. Ask custodians to leave the lights on for your inspection. If you have to enter a dark room, turn on the lights and remain motionless for a few minutes. The roaches will soon resume their activity. Once you see the roaches, you can move. Your movement will frighten them into running back to their hiding places. Inspect these spots to determine whether they

are actual harborage or pathways to harborage in another area. Note this information on your map.

Flushing with a Repellent Insecticide

This should not be necessary, especially if you conduct thorough inspections and include at least one night inspection. Do not use this technique in rooms with cockroach traps, baits, or bait stations because roaches will avoid them after you have sprayed.

If you do encounter situations where it is necessary to flush roaches from a suspected hiding place, use just a 1-second blast from a small can of aerosol pyrethrin; no more is required for effective flushing.

Where to Inspect

When inspecting for roaches, check the following areas:

- in corners of rooms at floor or ceiling level
- under, behind, and around sinks, toilets, showers, bathtubs, drinking fountains, ice machines, dishwashers, beverage dispensers, floor drains
- the engine compartments of refrigerators, beverage dispensers, toasters, air conditioners, and other equipment
- in and under stoves, hot plates, heaters, and near hot water pipes and radiators
- in and around stove vents, hoods, grease traps
- between equipment and walls
- behind picture frames, mirrors, bulletin boards, wall-mounted shelving
- in false ceilings, vents, light fixtures, ceiling-mounted fixtures, and railings
- in cupboards, linen closets, drawers, filing cabinets, lockers, cluttered areas
- in and under cash registers, computers, telephones, electric clocks, televisions, switchboxes, and fuse boxes
- in and around check-out stands, vegetable bins, and meat counters
- cracks and crevices in walls, baseboards, etc.
- under edges and in corners of equipment, tables, desks, counters, and other furnishings and equipment
- indoor and outdoor trash containers, dumpsters, and recycling containers
- loading docks, and storage areas where incoming food, supplies, equipment, and other potential sources of migrating roaches are received and stored

Trapping

A visual inspection may not provide all the information you need about where roaches are harboring or how many roaches there are; you may need to use sticky traps as well. Many brands of sticky traps are available, but most are of a similar design—a rectangular or triangular cardboard box with bands of sticky glue inside and, in some models, a dark strip of cockroach attractant.

The best sites for traps are along the roaches' normal travel routes as they move from harborage to feeding areas. Roaches will not seek out traps located outside these travel routes. Avoid placing traps in extremely dusty areas because they will quickly lose their stickiness. Initially, put out as many traps as possible. The more traps used, the sooner the concentrations of roaches can be located. Later, you can use fewer traps for ongoing monitoring. Try to “think like a roach” as you decide where to place the traps. Your monitoring map and the following examples will help you to determine the best spots.

Trap Locations

Keeping in mind the habitats preferred by roaches (refer to Table 6-1), place the traps in the following types of locations:

- near and under sinks and stoves
- in or near motors of refrigerators and other appliances or vending machines
- in or near electric clocks, switch plates, and conduits
- next to computer equipment (where possible)
- near leaky plumbing fixtures
- near steam pipes or hot water pipes with insulating jackets
- near drains
- in drawers and cupboards
- in closets, on their floors and upper shelves
- in false ceilings or subfloor areas
- in areas where packaged goods and equipment are delivered and stored

Trap Placement

Once the general locations for setting out traps have been decided, it is important to place the traps along the periphery of rooms or other objects as this is where roaches travel. Traps set out in the open away from walls or other “edges” are unlikely to catch roaches.

Box 6-A.

Tools Used To Monitor For Cockroaches

- **Flashlight.** Use a heavy-duty, corrosion-resistant model with a bright-colored body, shatter-proof lens, and halogen bulb. A smaller halogen flashlight with a flexible neck is useful in tight, confined locations. Flashlight holders that can be attached to a belt are available.
- **Telescoping Mirror.** Use a furnace inspector's or mechanic's metal mirror with a telescoping handle and rotating head. To illuminate areas inside equipment, fixtures, etc., reflect the flashlight beam off the mirror.
- **Clipboard and Pen.** Use the clipboard to carry monitoring forms, floorplans, etc. during inspections.
- **Floorplan Maps and Building Plans.** Carry a floorplan with the major equipment and fixtures marked. In large buildings, construction drawings which show utility lines, heating/cooling ducts, shaft connections, pipe chases, etc. are very useful for locating entry points, harborages, and runways.
- **Sticky Traps.** These are used to locate harborage areas and estimate populations.
- **Flushing Agent.** A pocket-sized can of pyrethrin flushing agent is useful for spot-flushing roaches out of inaccessible areas where trapping is not sufficient.
- **Utility Tools.** A pocketknife equipped with various blades, screwdrivers, and forceps allows you to open grills, electrical boxes, and other equipment for inspections. Carry small vials and adhesive labels to collect cockroach specimens. A 10-power (10x) hand lens (small magnifying glass) will help you identify roach species. Colored adhesive labels can be used to mark hot spots, location of traps and bait stations, etc. These tools can be stored in a tool pouch worn on a belt.
- **Knee Pads and Bump Cap.** These are useful when crawling around for floor-level inspections.
- **Camera.** A Polaroid camera is useful for communicating specific conditions (e.g., unsanitary conditions, areas needing pest-proofing, etc.) in reports to decision-makers or sub-contractors not on the premises.

Examples of edges include the intersection of

- floors and walls
- floors and cabinets or other solid furnishings
- floors and appliances such as stoves, refrigerators, vending machines
- counters and walls
- hanging cabinets or shelves and walls

Place each trap so the opening is perpendicular to the wall, countertop, etc. so a roach traveling along the edge of the floor or wall can walk into the trap (see Figure 6-2).

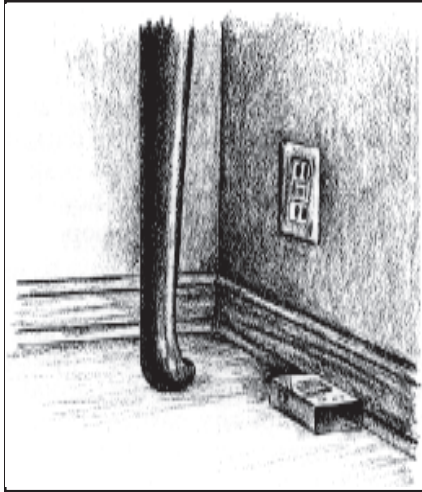


Figure 6-2

Number and date each trap, and mark on your monitoring map. After 24 to 48 hours, count and record the number of roaches in each trap. Record the date and the number of roaches on both the trap and the monitoring form.

Evaluating Trap Counts

- Traps with the highest numbers of roaches indicate a nearby harborage, and this is where management efforts should be concentrated.
- Traps with few or no roaches should be moved to other locations until all main harborage areas are pinpointed.
- When traps contain large numbers of small nymphs, this may indicate that the roach population is being stressed by such factors as scarcity of food and water, or it may indicate overcrowded harborage since nymphs generally remain within the harborage.
- Large numbers of adults in the traps can indicate a population explosion.

On-Going Monitoring

Sometimes it is useful to continue counting the roaches in each trap every 24 to 48 hours for a week or two. This can give you a clearer picture of the population and, if it is small, the trapping may eliminate it. Where

roaches rarely invade, you can check traps every 2 or 3 months (be sure to replace traps when they are full or no longer sticky). In cafeterias and other food-handling areas, check traps every month.

Monitoring to Evaluate Treatment Efficacy

Monitoring traps can provide information on the effectiveness of management efforts. To see how well treatment efforts are working, put out fresh traps a week or so after implementing the treatment methods selected from the Management Options below, and count the roaches in the traps 24 hours later. If the roach population has dropped considerably, progress has been made. If not, greater efforts must be made to eliminate food sources and reduce harborage. In order to assess the continued success of treatments and detect any new infestations, continue to monitor after the IPM program is underway. Vigilance is important.

Monitoring to Determine Roach Tolerance Levels

It may be impossible to eliminate cockroach infestations completely, especially in urban situations. Very old buildings may have more roach harborage than can be eliminated in any practical way, and there is always the possibility of reinfestation from roaches traveling in handbags, backpacks, clothing, used furniture and appliances, and packing materials. Because of these problems, it may be necessary to live with a certain small number of roaches. The sticky traps can help determine what this number is, since it is possible for the roach population to be low enough that the traps catch a few roaches, but no one notices any in the course of a normal day. This is considered the tolerance level and will differ depending on location, time of year, health department regulations, and availability of management resources.

Determining the number of roaches that can be tolerated will take time and experience, and will have to be done after you have reduced the cockroach population through the appropriate treatments. First you will need to ascertain the average number of roaches caught in a designated area, and then you must correlate this figure with the perceptions of the people using the area.

Set out a certain number of traps (say 10) in a certain area (perhaps the kitchen), and leave them there for a certain period of time (a week). The number of traps

Sample IPM Program for a Cockroach Infestation in a Kitchen

1. Use sticky traps to locate roach habitat and prioritize areas to be treated.
2. Knock-down the roach population by vacuuming areas where traps indicate roaches are harboring; steam-clean infested kitchen equipment and appliances if possible.
3. Initiate an education program for students, staff, custodians, and building maintenance personnel to gain cooperation for the next steps.
4. Improve sanitation and waste management procedures to reduce roach food sources.
5. Reduce roach access to water and habitat by repairing water leaks, caulking cracks, and scheduling other building repairs.
6. If the previous activities have failed to reduce roach numbers sufficiently, apply insecticidal dusts, baits, or gels in cracks and crevices in hard-to-clean areas; blow boric acid or silica aerogel into wall or ceiling voids, underneath appliances, or in other inaccessible areas where roaches harbor.
7. After the adult roach population has been reduced, apply an insect growth regulator to help prevent future roach problems.
8. Monitor weekly and fine-tune management methods as needed until the problem has been solved. Continue monitoring monthly or quarterly to insure sanitation measures are maintained and to detect any incipient buildup of roach numbers.

that you use in the area and the length of time you wait before counting must remain the same each time you make an assessment if your estimation is going to be accurate. When you make your counts, find the average number of roaches per trap by dividing the total number of roaches by the total number of traps. Record this information on your monitoring form, and write on each trap the date and the number of roaches inside. Question the people using the area you are monitoring to see if they have noticed any evidence of cockroaches. Record this on your monitoring form. If the traps are still sticky, leave them out for another week and count the roaches again.

Once you have done this for a number of weeks you will begin to be able to correlate the number of roaches caught in your traps with the number that can be tolerated. Use this number as a baseline, and be aware that it may differ depending on the area and the people using the area. When the number of roaches caught is above the baseline, renewed sanitation efforts and other treatments may be justified. When the number is at or below the baseline, you don't need to do anything except continue to monitor.

MANAGEMENT OPTIONS

Education

Food service and custodial staff play an essential part of any successful roach management program. Provide them with information on how to maintain roach-free kitchens, dining rooms, and waste disposal areas by applying the methods described below. Teachers, students, and other staff also play a significant role in maintaining a high level of sanitation in other areas of the school, so they must be informed of their responsibilities in that regard.

Habitat Modification

Cockroaches need food, water, and harborage to survive, and the harborage must be at the proper temperature. By modifying the environment of an infested building, you can reduce roach access to these resources. With good-quality materials and a careful job, the alterations will produce a long-term reduction in the capacity of the structure to support roaches. It is important to note that the simple act of increasing the distance between food, shelter, and water will dramatically reduce the number of roaches an environment can support. Eventually the cockroaches, especially the

young, will have to expend excessive energy to get from harborage to food or water, and they will die.

Limiting Areas for Eating

If you expect to contain and limit pest problems (ants and rodents as well as cockroaches), it is very important to designate appropriate areas for eating and to enforce these rules. The fewer designated areas, the easier it will be to limit the pests.

Eliminating Cracks and Crevices

- It is not necessary to seal all cracks. Start by caulking where roach populations are highest. If roaches remain a problem, caulk additional areas.
- Use silicon caulk or mildew-resistant caulk around sinks, toilets, and drains.
- Before beginning the sealing process, vacuum and wash the area to eliminate all egg cases, fecal material, or other debris.
- Caulk or paint closed cracks around baseboards, wall shelves, cupboards, pipes, sinks, toilets, and similar furnishings in the locations suggested by trap results.
- Repair small holes in window screens with clear caulk.
- Weather-strip around doors and windows where cockroaches may enter.
- Where gaps can't be sealed, they can be widened to make them less attractive to roaches. For example, the crack between free-standing shelving and adjacent walls can be widened by simply moving the shelving one inch away from the wall. An inch-wide gap is not attractive to roaches.

Eliminating Clutter

Removing clutter from areas near prime habitat such as sinks, stoves, refrigerators, vending machines, etc. is one of the most important components of sanitation. Clutter in these areas vastly increases the available harborage that is conveniently near the cockroaches' food and water sources. For example, in kitchens, boxes should be broken down and stored in a cool or unheated area preferably near the loading dock but definitely isolated from the main kitchen.

Sanitation

Sanitation eliminates food and harborage and can play a part in slowing the cockroach life cycle by scattering them as they search for new harborage (their life cycle is shorter when they are grouped together). This

Sample IPM Program for a Roach Population in an Office or Classroom

1. Initiate an education program for students, staff, custodians, and building maintenance personnel to gain cooperation with the program. Since monitoring and management activities will probably involve desks, computers, lighting fixtures, and other equipment in use by staff, it is essential that they be given prior warning of work to be done and that the problem can not be solved without their cooperation.
2. Place sticky traps to locate roach habitat and prioritize areas to be treated.
3. Vacuum areas where traps indicate roaches are harboring.
4. Improve sanitation and waste management in office, snack, and lunch areas to reduce roach food sources.
5. Caulk cracks, and schedule other building repairs to reduce roach habitat.
6. If traps indicate roaches have infested computers or other electrical equipment, place insecticidal bait stations next to infested machines. Never put baits directly on or inside computers or electrical equipment. Never use aerosol insecticides around computers because of the danger of shorting out the equipment. Give office and custodial staff a map showing where bait stations have been placed and request that the stations not be moved.
7. If traps indicate that roaches have infested electrical conduit and are moving into the room through lighting switch plates, spot-treat the switch box with insecticidal bait, gel, or dust.
8. If traps indicate storage boxes containing paper files are infested with roaches, enclose file boxes in large plastic bags and fumigate with carbon dioxide.
9. If the previous activities have failed to reduce roach numbers sufficiently, apply insecticidal bait, gel, or dust in cracks and crevices, and blow insecticidal dusts into wall or ceiling voids, underneath counters, or in other inaccessible areas where roaches harbor.
10. After the adult roach population has been reduced, apply an insect growth regulator to help prevent future roach problems.
11. Continue monitoring until the roach population has been reduced to a tolerable level. Circulate a memo announcing that the roach problem has been solved and thank staff for their cooperation. Return monthly or quarterly to place and inspect traps to insure roach numbers remain within tolerable levels.
12. If monthly monitoring indicates roach populations are starting to rise, renew sanitation efforts and consider experimenting with releases of cockroach parasitoids while roach numbers are still relatively low.

disruption can also help to bring more individual roaches into contact with toxic baits or insecticidal dusts (see Chemical Controls below).

Thorough daily cleaning of kitchens is essential:

- Sweep and mop the floors.
- Drain all sinks and remove any food debris.
- If children regularly receive snacks in classrooms, vacuum and/or mop these floors daily.
- Periodically, give all food preparation areas an all-inclusive cleaning, focusing on areas where grease accumulates: drains, vents, deep fat fryers, ovens, and stoves. Steam-clean drains and infested appliances. Survivors driven out by the steam can be caught in traps placed nearby. Thoroughly vacuum the area with a powerful vacuum cleaner (see the section below on vacuuming).
- At the end of each day, remove from the building all garbage containing food to prevent cockroaches from feeding at night.
- Use soapy water to wash any bottles, cans, wrappings, and other items that have food residues clinging to them before storing them for recycling.
- If dishes cannot be washed right away, it is very important that they at least be rinsed to remove all food debris.
- Place garbage in sealed plastic bags before it is placed into a rodent-proof dumpster or other storage receptacle.
- Keep garbage cans and dumpsters as clean as possible to deny food to roaches as well as ants, flies, mice, and rats.

Brownbanded cockroaches can survive without free-standing water, and they can live on soap or the glue on stamps, so simple sanitation will not make as significant an impact on a brownbanded roach population as it will on German roaches.

Proper Food Storage

- Food not kept in the refrigerator should be kept in containers that close tightly. Cardboard boxes and paper are not roach-proof.
- Screw-top jars are roach-proof only if the lid has a rubber seal since the roaches can follow the spiral ridges to get into the jar.
- Glass containers with rubber gaskets or plastic containers with tight-fitting, snap-top lids are also roach-proof.
- Transfer food packaged in paper to plastic or glass containers as soon as the food arrives in the building.

Do not bring shipping boxes into the food preparation area. Instead, boxes should be broken down and stored away from the kitchen in a cool area until removed for recycling.

- Advise students and teachers not to leave unsealed food items in their desks or lockers. Any food kept in offices or classrooms should be stored in ant- and roach-proof containers.

Installing Roach-proof Fixtures and Appliances

Whenever food preparation areas are scheduled for remodeling, the school district can take the opportunity to install roach-proof kitchen appliances and fixtures, such as stainless-steel open shelving units. The round shape of the metal and the general openness of the design offer few hiding places for roaches. Free-standing storage units and appliances on castors enable them to be rolled away from walls to facilitate thorough cleaning.

Eliminating Water Sources

The German roach survives longer on water alone than on food alone. And it survives longer without food or water if the relative humidity is higher; thus reducing the available drinking water and humidity are high priorities. Roaches find drinking water in

- sink traps
- appliance drip pans
- drain pipes
- wash basins and tubs
- toilet bowls and flush tanks
- spills
- condensation on cold-water pipes and windows
- leaky pipes and faucets
- pet dishes and aquariums
- vases
- beverage bottles
- various high-moisture foods

Much can be done to cut back this supply through repairs and barriers. Repair dripping faucets and any other leaks, and drain or ventilate moist areas. Keep kitchen surfaces dry whenever they are not in use, especially overnight.

Removing Vegetation

Some roaches live primarily outdoors in the decaying vegetation of the garden and forest. Examples include

the brown roach and the field cockroach. In cases where these roaches periodically come into the school, it is essential to remove decaying vegetation from foundations, leaving a clean border. Outdoor planter boxes and other structures close to the school where moisture and decayed organic material collect should also be monitored.

Physical Controls

Screening Vents and Windows, and Sealing Off Runways

Cockroaches can travel throughout a building and from building to building on runways such as electrical conduits, heating ducts, and especially plumbing pipes. Seal these runways with caulk, window screen, or other appropriate materials.

Roaches may also travel up the outside of the building and enter through an open window, weep hole, or ventilation duct. Screening these openings prevents roaches from using them as entry points. Screens can also be placed behind grill covers and over vents or floor drains to prevent roach entry. Use caulk around the edge of the screen to make a tight seal.

Vacuumping

A strong vacuum can be used to pick up roaches, including their egg cases and droppings, as well as debris that drops behind appliances or furniture and feeds the pests. If you are dealing with a huge roach population that must be knocked down immediately, a thorough vacuuming will be very effective. Once you have vacuumed up a large portion of the roach population, it will be easier to begin habitat modification.

A crevice attachment will suck roaches out of cracks, and the hose end alone can pull roaches out from under appliances, or from cupboards or upholstered furniture. If the vacuum is capable of filtering out very small particles (0.3 microns), it will greatly reduce the amount of cockroach effluvia that is blown around during cleaning. It is this effluvia that can cause allergic reactions.

Although the dust in the vacuum bag will usually clog the roaches' breathing apparatus and suffocate them, you can vacuum up a tablespoon of cornstarch to be sure they die.

Trapping

In certain limited situations traps can also be used to reduce roach numbers. For example, the University of

California used sticky traps to help control roaches in animal-rearing rooms where no insecticides were allowed (Slater et al. 1980). Traps can also capture a few roaches that might be dislodged during construction, introduced into roach-free areas on furniture or packaging, or forced into the area when an adjacent room is sprayed with an insecticide.

When traps are used to reduce populations of roaches, leave them in place until they are full. In most situations, however, trapping alone will not produce a sufficient degree of control.

Biological Controls

One parasitoid has been used in a precedent-setting project to control the brownbanded cockroach in a large research building on the campus of the University of California at Berkeley. The roach population had become a significant problem, but because laboratory animals were being raised in this research facility, pesticides could not be used (Slater et al. 1980).

Researchers imported the egg parasitoid *Comperia merceti* from Hawaii, where it was known to be effective against the brownbanded roach. The parasitoids are so tiny—less than half the size of the roach egg capsule—that even the periodic releases of 20,000 at a time went unnoticed by the people who worked there. The fact that the building contained animal-rearing labs where food, water, and animal fecal matter were always available for roaches to feed on makes the high degree of control achieved in this project even more impressive.

Although *Comperia merceti* only attacks the brownbanded roach, another parasitoid, *Tetrastichus hagenowi*, has been found to be effective against the German, American, oriental, and smoky brown roaches.

The use of natural enemies of roaches cannot by itself be expected to solve cockroach problems. Roach control must always involve sanitation and habitat modification as described above, and, in most cases, the judicious use of chemical controls.

Chemical Controls

If non-chemical methods alone prove insufficient to solve the problem, then integrating a pesticide into your management program may be warranted. For information on the hazards of various pesticides and on how to select an appropriate pesticide for your situation, consult Appendix G for a list of resources.

Pesticides must be used in accordance with their EPA-approved label directions. Applicators must be certified to apply pesticides and should always wear protective gear during applications. All labels and Material Safety Data Sheets (MSDS) for the pesticide products authorized for use in the IPM program should be maintained on file. Do not apply these materials when buildings are occupied, and never apply them where they might wash into the sanitary sewer or into outside storm drains.

When insecticides are needed, they should be applied as dusts in crack and crevice treatments or in bait form. Broadcast spraying of insecticides will do more to scatter the cockroaches than it will to control them. This makes them more difficult to find and the pest manager must expend more time and effort baiting in the new scattered locations.

Never use aerosol insecticides around computers because of the danger of short-circuiting the equipment. Use baits near computers but do not place loose bait inside the computer or on the keyboard. When cockroaches have infested computer equipment, small quantities of dry formulations can be inserted into 2-inch lengths of plastic drinking straw and taped to the computer in inconspicuous places.

Resistance to Insecticides

Insecticide resistance in cockroaches is a growing problem. Many residual poisons no longer affect cockroaches. So far, there is no documented resistance to boric acid, diatomaceous earth, or silica gel, and because of the way these insecticides work, resistance in the future is unlikely. There is no guarantee, however, that the other insecticides mentioned here will be useful forever.

There are three types of materials available for roach control: insecticidal dusts, insecticidal baits, and insect growth regulators. These materials take 5 days or longer to kill substantial numbers of roaches, and it can take weeks to suppress large populations to the point where none are seen. However, once this point has been reached, and if parallel steps are taken to reduce roach food and harborage, you can expect long-term relief from roach infestations.

Boric Acid

Boric acid is one of the most valuable chemical control tools in an integrated program against roaches. It is formulated as a powder, paste, and aerosol. It acts as a stomach poison and is one of few materials that does not

repel cockroaches, so they are not able to avoid it as they do other compounds. The powder and paste formulations do not vaporize into the air as do conventional sprays. Furthermore, if kept dry, it remains effective for the life of the building.

Wear a dust mask when applying boric acid powder. A very light dusting in cracks and crevices is superior to dusting large open areas. Cockroaches will avoid piles of boric acid. Boric acid is approved for crack and crevice treatment in food handling areas. It can be blown into areas of prime habitat, such as under refrigerators or into cracks in the inner recesses of cabinets and cupboards, whether or not roaches are present.

There are a number of products on the market now that contain boric acid. In general, boric acid works better alone than when it is mixed with other insecticides. Some boric acid products contain additives which improve their effectiveness or the safety of their use, such as anti-caking agents, bitter-tasting compounds, and dyes.

Boric acid has also been formulated into baits (see discussion below for general information on baits).

Diatomaceous Earth and Silica Aerogel

These are insecticidal dusts that can be used for roach control, but they are more repellent to roaches than boric acid. Diatomaceous earth is made from fossilized diatoms, and silica gel is produced essentially from sand. Both kill insects by desiccation; they absorb the wax and oil from the insect's outer covering, which causes dehydration and death. Although these materials are not poisonous to humans directly, the fine dust travels freely through the air and can be irritating to the eyes and lungs; therefore, use a dust mask and goggles during application.

Diatomaceous earth and silica aerogel are especially useful in wall voids and similar closed spaces. During construction and remodeling these dusts can be blown into such spaces, and in finished buildings they can be applied by drilling tiny holes in the walls. These dusts are also useful in crack and crevice treatments.

Some products combine diatomaceous earth or silica gel with pyrethrins. The pyrethrins provide a quick knock-down of the cockroaches, and the dusts provide the long-term control.

Cockroach Baits

In general, baits help to reduce the amount of pesticide used against a pest because the pest is attracted to

discreet locations where it comes into contact with the poison; the pesticide doesn't need to be spread around all over the environment. Baits work best where sanitation and physical modifications are also employed so that the bait is not competing with freely available roach food.

Bait Placement Tips

According to Dr. Austin M. Frishman (Frishman 1994), there are a number of tricks to placing bait properly.

- Large blobs of baits in a few locations do not work well because German cockroaches don't easily find food that is any distance from their harborage. Put out small amounts of bait in many locations.
- Put bait near harborage and between harborage and food. Review the Monitoring section for examples of roach harborage, and use the information collected from your monitoring traps.
- Once you have pinpointed harborage areas, place the baits along edges or in places where roaches are most likely to travel or congregate. If the bait is between the harborage and the food but not in a place where roaches are likely to run into it, the baiting program will fail.
- Sometimes an inch one way or the other can make all the difference in bait placement. If air currents are moving the bait odors away from the cockroach harborage, they will never find the bait.
- Make sure that the surface of the bait will not get covered by excessive grease, flour, or dust. In areas where this might be a problem, such as near french fry preparation, the bait must be protected.
- Harsh environments pose various problems in a baiting program. In very warm areas baits can melt and run, in cold environments the cockroaches don't move far and may miss the bait, and in very warm and wet environments the baits may grow mold that renders them unattractive to roaches. Boric acid baits hold up better in the last situation because boric acid naturally inhibits mold growth.
- Check baits frequently to make sure that someone has not inadvertently painted over them or accidentally knocked them off while cleaning, etc.
- If new cockroaches are moving in so fast that it appears that the baits are failing, you may need to elicit more help from the school staff in preventing

contaminated goods from coming into areas of prime habitat.

As Dr. Frishman notes, "Keep in mind that you are trying to control living organisms. It is not a simple mathematical formula that works every time. You sometimes have to adjust what you did to get the baits to do the job. I call it 'tweaking the baits to perfection.'"

Active Ingredients Used in Baits

Abamectin—an extract from the naturally occurring soil microorganism *Streptomyces avermitilis*.

- available as a dust, spray, or gel
- can be applied only by a commercial pest control operator
- works both as a lethal internal toxicant and as a contact insecticide when roaches groom themselves and ingest the bait
- takes a week or longer to kill 70 to 90% of the roaches, may take 12 weeks to achieve 100% kill
- should be used in cracks and crevices and in other inaccessible places near harborage
- not registered for use in food preparation or food handling areas.

Boric Acid—a general enzyme-inhibitor.

- available as a paste either in bulk or in a cartridge for bait gun application.
- available as a weather-resistant, granular bait
- also available as a "fine granular" bait that can be used in a bulb duster for interior crack and crevice treatment (the advantage of a granular bait is that roaches are exposed by contact as well as by ingestion)
- use dust mask and goggles during application

Hydramethylnon—a slow-acting stomach poison that must be ingested to be effective.

- Roaches die within 2 to 8 days after feeding on the bait.
- Available in a plastic disk as well as a gel.
- Disks come with a double-sided tape so they can be glued to various surfaces out of view. The tape also facilitates placement of the bait stations on the undersides of drawers, on walls.
- Two to 3 discs per 100 square feet of horizontal surface area are recommended. This may not be enough bait stations when roach numbers are high,

and the bait will be used up quickly leaving the empty stations as excellent roach harborage.

- If you see roaches inside stations, they are probably using the discs as harborage after having eaten all the bait. Put these discs into a plastic bag, seal, and discard.
- The bait may last for several months if roach numbers are low to moderate, but the bait stations should be checked 4 to 6 weeks after installation.
- Although hydramethylnon is less repellent when it is used in a bait station, the gel formulation is useful in situations where it is difficult to place a bait station. Inspect bait locations each week reapply if bait has been depleted. Do not place bait gels on surfaces that will be washed because the bait will be washed away. Hydramethylnon gels are not registered for use in food preparation or storage areas.

Metarhizium anisopliae—a fungus that has been tested rather thoroughly over the last hundred years. Because it cannot grow at temperatures greater than 95°F, it does not infect humans or other mammals.

- Bait stations do not contain a food attractant; roaches are attracted to the water in the formulation.
- Roaches are infected when they touch the fungus as they enter the station.
- Individuals carry the pathogen back to their harbor-age to infect other roaches.
- It takes 4 weeks or longer to kill 80% of the roaches, and may take 5 or more weeks to achieve 100% kill.
- Do not place bait stations near radiators or other sources of heat as heat will destroy the fungus.
- Direct exposure to sunlight might also kill the fungus.

Insect Growth Regulators (IGRs)

IGRs, such as hydroprene, are synthetic versions of the juvenile hormones insects produce to regulate development from their immature to adult stages. Because many of the worst cockroach infestations occur in settings where migration from one infested area to another takes place, new adults can continue to move into areas where IGRs have been applied and the new roaches will not be affected. As a result, use of IGRs makes sense only if they are combined with other tactics

such as roach exclusion, reduction of access to water, food and harborage, and application of an adulticide such as boric acid.

- IGRs do not kill insects directly. Their most important effect is to cause immature roaches to become sterile adults and eventually die without reproducing. But those roaches that are already adults before they come into contact with an IGR will keep on reproducing.
- IGRs are best applied after heavy roach infestations have been reduced to low levels and every effort has been made to eliminate harborage or opportunities for roaches to migrate in from other areas. When IGRs are used this way, the small number of immature roaches that survived suppression efforts (perhaps because they were still inside egg capsules when the cleanup took place) will encounter the IGR and fail to mature and reproduce. Adults that survived the cleanup may produce young before dying, but their young will be sterilized by the IGR. Theoretically, the IGR will eventually eliminate the remnant cockroach population.
- For brownbanded control, the IGR should be sprayed in prime egg-laying habitat (rough, dark places) so that when eggs hatch the nymphs will be exposed immediately to the material.
- To monitor the effectiveness of IGR use, place sticky traps in areas where roaches are known to travel. Immature roaches that have been exposed to an IGR become adults that are darker in color and somewhat distorted in appearance (they have twisted wings). When you begin finding these roaches in the traps, you know the reproduction rate is being lowered.

Carbon Dioxide Fumigation

Carbon dioxide gas (CO₂) can be used to kill cockroaches when they have infested cartons of papers, clothes, or other stored materials.

- Loosely fill a heavy-duty plastic garbage bag with the infested items, and insert the end of a vacuum hose into the bag to suck out as much air as possible.
- Tightly seal the bag using duct tape to reinforce all seams.
- Finally, insert a hose from a CO₂ canister into a small opening cut in the top side of the bag. Fill the bag

with undiluted CO₂ from the canister, remove the hose, and seal the hole with duct tape. Leave the bag sealed overnight.

- When the bag is opened, roaches will either be dead or extremely sluggish and will die a short time later without further treatment.

BIBLIOGRAPHY

- Bio-Integral Resource Center (BIRC). 1996. 1997 directory of least-toxic pest control products. *The IPM Practitioner* 18(11/12):1-39.
- Cochran, D.G. 1994. How resistant are they? *Pest Management* 13(6):14-16.
- Daar, S. 1987. Boric acid: new formulations and application equipment. *The IPM Practitioner* 9(6/7):3-4.
- Frishman, A. 1994. 15 ways to misuse German cockroach baits. *Pest Control* 22(4):23,67.
- Mallis, A. 1982. *Handbook of Pest Control*. Franzak and Foster, Cleveland, OH. 1,101 pp.
- Moore, W.S. and T.A. Granovsky. 1983. Laboratory comparisons of sticky traps to detect and control five species of cockroaches (Orthoptera: Blattidae and Blattellidae). *Journal of Economic Entomology* 76(4):845-849.
- Olkowski, W., S. Daar, and H. Olkowski. 1991. *Common-Sense Pest Control: least-toxic solutions for your home, garden, pets and community*. Taunton Press. Newtown, CT. 715 pp.
- Olkowski, W., H. Olkowski, and S. Daar. 1983. *The German Cockroach*. Bio-Integral Resource Center, Berkeley, CA. 22 pp.
- Olkowski, W., H. Olkowski, and T. Javits. 1979. *The Integral Urban House*. Sierra Club Books, San Francisco. 494 pp.
- Owens, J.M. and G.W. Bennett. 1983. Comparative study of German cockroach (Dictyoptera: Blattellidae) population sampling techniques. *Environmental Entomology* 12:1040-1046.
- Quarles, W. 1995. Least-toxic baits for roaches. *Common Sense Pest Control Quarterly* 10(1):5-12.
- Slater, A., M. Hurlbert, and R. Lewis. 1980. Biological control of brown-banded cockroaches. *California Agriculture* 34(8/9):16-18.
- Snetsinger, R. 1989. A paper on the use of diatomaceous earth (as the product Shellshock®) for cockroach control, delivered at the 1989 annual meeting of the Entomological Society of America. *The IPM Practitioner* 12(2):6.